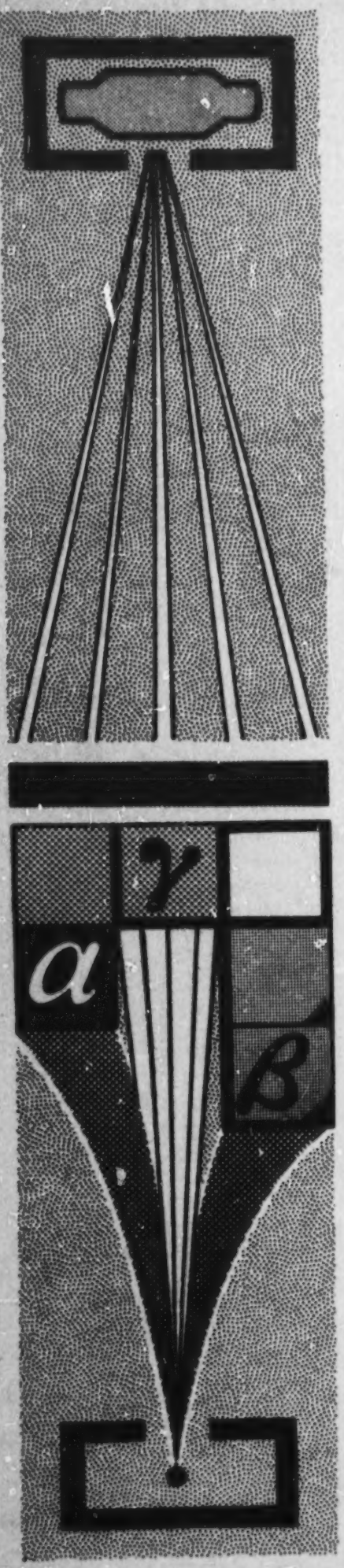
PB 184546



X-RAY EMISSION from SHUNT REGULATOR TUBES for COLOR TELEVISION RECEIVERS

Reproduced by the
CLEARINGHOUSE
for Federal Scientific & Technical
Information Springfield Va. 22151

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

25

MORP 67-1

X-RAY EMISSION from SHUNT REGULATOR TUBES for COLOR TELEVISION RECEIVERS

by
Emmet Murphy, Harold Stewart, Steven Coppola, and Norman Modine

X-RAY EXPOSURE CONTROL LABORATORY
MEDICAL and OCCUPATIONAL RADIATION PROGRAM

JUNE 1967

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

Bureau of Disease Prevention and Environmental Control
National Center for Radiological Health
Rockville, Maryland - 20852

The laboratory study by Emmet Murphy, Harold Stewart, Steven Coppola and Norman Modine on "X-ray Emission from Shunt Regulator Tubes for Color Television Receivers" is preliminary and describes technical problems that must be overcome in developing an effective design for measuring X-radiation from color television receivers. A reasonably accurate estimate of the exposure of people both in terms of number and parameters which would help evaluate possible effects on people would require extensive field and scientific investigations. This laboratory study should aid in developing a proper design of these investigations.

James G. Terrill, Jr.
Director, National Center for
Radiological Health

CONTENTS

Introduction 1

Description of Shunt Regulator Tube Function and X-ray Emission 1

Results of Shunt Regulator Tube X-ray Surveys 2

Quality of X-ray Beam from Shunt Regulator Tubes 3

Measurement of Radiation Levels in the Vicinity of Television Receivers 4

Conclusions 4

Illustrations

Figure 1 - Shunt Regulator Tube Construction 5

Figure 2 - Photograph and Radiograph of Typical Shunt Regulator Tubes 6

Figure 3 - Photograph of Experimental Setup and Arrangements for Surveying Shunt Regulator Tubes 7

Figure 4 - Variations in Images of X-ray Leakage from Misaligned 6EF4 Tubes 8

Figure 5 - Characteristic Curves of Kodak Royal Blue Film, Density versus Exposure 9

Figure 6 - Radiograph (5" x 7") of the Lateral and Oblique Projection of X rays Emitted from Misaligned 6EF4 Tube No. 10 10

Figure 7 - Aluminum Absorption Curve of X rays Emitted from a 6LC6 Shunt Regulator Tube Operating at 25 kVp 11

Figure 8 - Depth Dose Curves Used in Mammography 12

Tables

Table 1 - Shunt Regulator Tubes for Color Television Receivers 13

Table 2 - Distribution and Exposure Rate of X-ray Leakage Below Shunt Regulator Tube 14

Table 3 - Intercomparison of Survey Meter Readings of Shunt Regulator Tube X Radiation 16

Bibliography 17

Appendices
Appendix A - Press Statement: General Electric Company 19
Appendix B - Press Statement: National Center for Radiological Health 20

Coordinate Index Cards 21

Introduction

The potential for exposure of individuals by the x rays generated in high voltage, high vacuum devices has long been recognized (1,2,3,4,5). Television receivers are the most common consumer product to use these devices. In order to limit the gonadal dose contribution from television receivers to a small fraction of that from natural background, the National Commission on Radiation Protection and Measurements (NCRP) recommended in 1960 that the exposure rate at 5 cm from any outer surface of a home television receiver should not exceed 0.5 mR per hour under normal operating conditions (6). The distance of 5 cm was specified to make practical the use of ionization chambers as detection devices. In 1960, the International Commission on Radiation Protection made a recommendation identical to that above (7). British Standard 415 of 1957 states, in part, "The X-radiation from any equipment containing electronic devices, such as high voltage cathode - ray tubes and rectifying valves, shall nowhere exceed 0.5 mr/h when measured on the outside surface of the equipment housing" (8). American manufacturers of bulbs for television picture tubes use special x-ray absorbing glass which, by its composition and thickness, should prevent emission of x rays in excess of the NCRP recommended maximum (9).

Some television receivers contain another source of x rays, the shunt regulator tube. Adequate protection against radiation from these tubes may be obtained by tube design and/or external shielding. In 1964, Hayashi et al reported on tests of Japanese color television receivers and their components (10). The researchers predicted on the basis of their radiation measurements that five per cent of Japanese television receivers of the type tested might produce an exposure greater than the ICRP recommended maximum, as a result of radiation from the shunt regulator tube. Recently, x-ray emissions from color television receivers greater than the NCRP recommended maximum have come to the attention of the Public Health Service (See Appendix). The source of this radiation was found to be the shunt regulator tube. This incident prompted further investigation by the Public Health Service of x-ray emission from shunt regulator tubes used in color television receivers.

Description of Shunt Regulator Tube Function and X-ray Emission

In color television picture tubes, the need to accurately focus three electron beams on the small bits of color phosphor requires precise regulation of the high voltage power supply. Some color television receivers use a shunt regulator tube for this purpose. Table 1 provides catalog information on some of the shunt regulator tubes used in color television receivers. Fig. 1 is a positive print of a radiograph of a typical shunt regulator tube, showing details of construction.

The shunt regulator tube operates at a constant high voltage and a varying low current. When the picture is bright, there is little current through the shunt regulator tube; a dim scene results in more current being shunted through this tube. Therefore, x rays of varying intensity, but constant potential, are produced at the target of the shunt regulator tube when the receiver is operating. The target is a square metal plate across the middle of the steel anode cylinder. Electrons from the indirectly-heated cathode pass a closely-wound control grid and are emitted through a large beam port in the focusing grid cap. Thus, with suitable control voltages, the electrons from the cathode are accelerated into the anode cylinder and strike the target plate, emitting x rays in all directions. The focusing grid cap is of sufficient diameter to intercept the x rays directed from the target to the base of the tube. The thickness of the steel anode cylinder is adequate to attenuate most of the x rays emitted in a lateral direction. A small misalignment of the focusing grid cap with the anode cylinder, or a small angular tilt of the anode, could allow x rays from the target to miss the focusing grid cap and pass through the glass envelope downward and to one side.

Adequate radiation shielding should be incorporated in the design of television receivers to prevent the emission of x rays. Industry's awareness of the possibility of x-ray emission from such electron tubes is indicated by the warning statements on some tube data sheets. For example, the General Electric Product Information sheet for the type 6EH4 tube states:

> "WARNING: Operation of this tube with the anode voltage above approximately 25 kilovolts or with a current of more than 0.5 milliamperes may produce soft X-rays which can constitute a health hazard on prolonged exposure at close range unless the tube is adequately shielded. The need for this precaution should always be considered in equipment design. Relatively simple shielding should prove adequate".

Results of Shunt Regulator Tube X-Ray Surveys

In order to observe the characteristics of x rays emitted from shunt regulator tubes, several 6EF4 and 6LC6 (Fig. 2) tubes were obtained from distributors in the Washington, D. C. area. These tubes were tested using a commercially available color television receiver, General Electric Model M278CWD with KC chassis, as the power supply. Since the position of the shunt regulator tube in the chassis is below and to one side of the picture tube, it is almost impossible to perform a radiation survey around the tube while it is in the receiver. Therefore, a tube test stand was set up remote from the set. A tube socket in the test stand was wired to the shunt regulator tube socket in the television receiver. With this experimental setup (Fig. 3), the radiation emission characteristics of various shunt regulator tubes could more easily be tested.

Figure 4 is a composite of radiographs showing how the pattern of radiation varies below the base of several different 6EF4 tubes, each with a different degree of misalignment. The current through the tube for these 1 hour exposures averaged 0.85 mA. These radiographs were made with 8" x 10" Royal Blue x-ray film in paper (Ready Pack) at a distance of 7 inches below the base of the tube. Table 2 relates the amount of misalignment of the 6EF4 and 6LC6 tubes tested, the resulting length and width of the crescent-shaped image, and the exposure rate at the point of maximum film darkening. It should be noted that each of the modified 6LC6 tubes with a lip on the lower edge of the anode cylinder had a lower leakage than the other tube types tested. This is because the lip helps to prevent escape of excessive amounts of x rays in cases of slight misalignment. Figure 5 is a calibration curve for Royal Blue x-ray film in paper (Ready Pack), used to determine the exposure rates from the film images.

Hayashi reported that the main leakage from the 6BK4 shunt regulator tubes was in a lateral direction (10). Similar leakage was observed in the film exposed to a 6EF4 tube, but the main emission of x rays was downward through the base of the tube (Fig. 6). These images were obtained by placing film in a plane through the long axis of the tube while it was operating. Figure 6 also illustrates that x rays are emitted from tubes with misalignment between the anode cylinder and focusing grid cap. There is little x-ray leakage above the target because the x rays produced are effectively shielded by the cap and target. For example, the half-value layer of iron is 0.065 mm for 25 keV photons. Thus, the 0.33 mm thickness of the anode cylinder is approximately five half-value layers for the most penetrating radiation generated.

Quality of X-Ray Beam from Shunt Regulator Tubes

To illustrate the quality of the x rays, an aluminum absorption curve for the x rays emitted from the 6LC6 tube is plotted in Fig. 7. These measurements were made using a Nuclear Chicago Model 2588 survey meter, with a thin end window Model 2526 medium range ionization chamber. This ionization chamber is reported to be correct within five percent for x rays in the energy region being investigated (11). Figure 7 shows the half-value layer of the beam to be 0.38 mm of aluminum, which corresponds to an effective energy of 16 keV (12). Hayashi et al obtained similar values from 6BK4 tubes (14). It should be noted that the x rays emitted by shunt regulator tubes are similar in quality to those used in diagnostic mammography. The depth dose curves for these x rays are shown in Fig. 8 (15). The skin erythema "dose" for these low energy x rays is probably 300 to 400 roentgens (16).

Measurement of Radiation Levels in the Vicinity of Television Receivers

X-ray leakage from television receivers can be detected with various portable instruments. However, the x-ray beams are narrow and may not fill the entire chamber volume. Thus the reading corresponds to an average intensity over the window area. Also, energy dependence will have a significant effect on the reading. Portable instruments are adequate for qualitative surveys of television receivers to determine if there is a problem of excessive x-ray emission. A more quantitative estimate of exposure rates requires indirect measurement by means of film calibrated for soft x rays. Table 3 shows readings obtained at a distance of 20 inches from one shunt regulator tube. The agreement between G-M counter and ion chamber readings indicated in the table cannot be expected unless the instruments are calibrated for radiation of the same energy. The Victoreen 440RF ion chamber was originally used because it is shielded against radio frequency interference; however, rf did not appear to interfere with readings on any of the instruments used. Osterkamp, et al (13) and Hayashi (14) used G-M counters for surveys of television receivers. X-ray film can also be used to locate radiation leakage, as in this study.

Conclusions:

The distribution and intensity of x-ray leakage from shunt regulator tubes were greater than previously reported.

It was found that the anode structure was not properly aligned with the focusing grid cap in some tubes. The amount of x-ray leakage was greatest from those tubes in which the misalignment was apparent. Thus, any misaligned tube is a potential source of x-radiation. Use of misaligned tubes as replacements in existing television receivers or as components of newly-produced receivers should be prevented. Also, external radiation shielding around the shunt regulator tube should be considered for inclusion in future receivers in order to limit the emitted radiation to the lowest practical level.

This study suggests the need for continued testing of shunt regulator tubes.

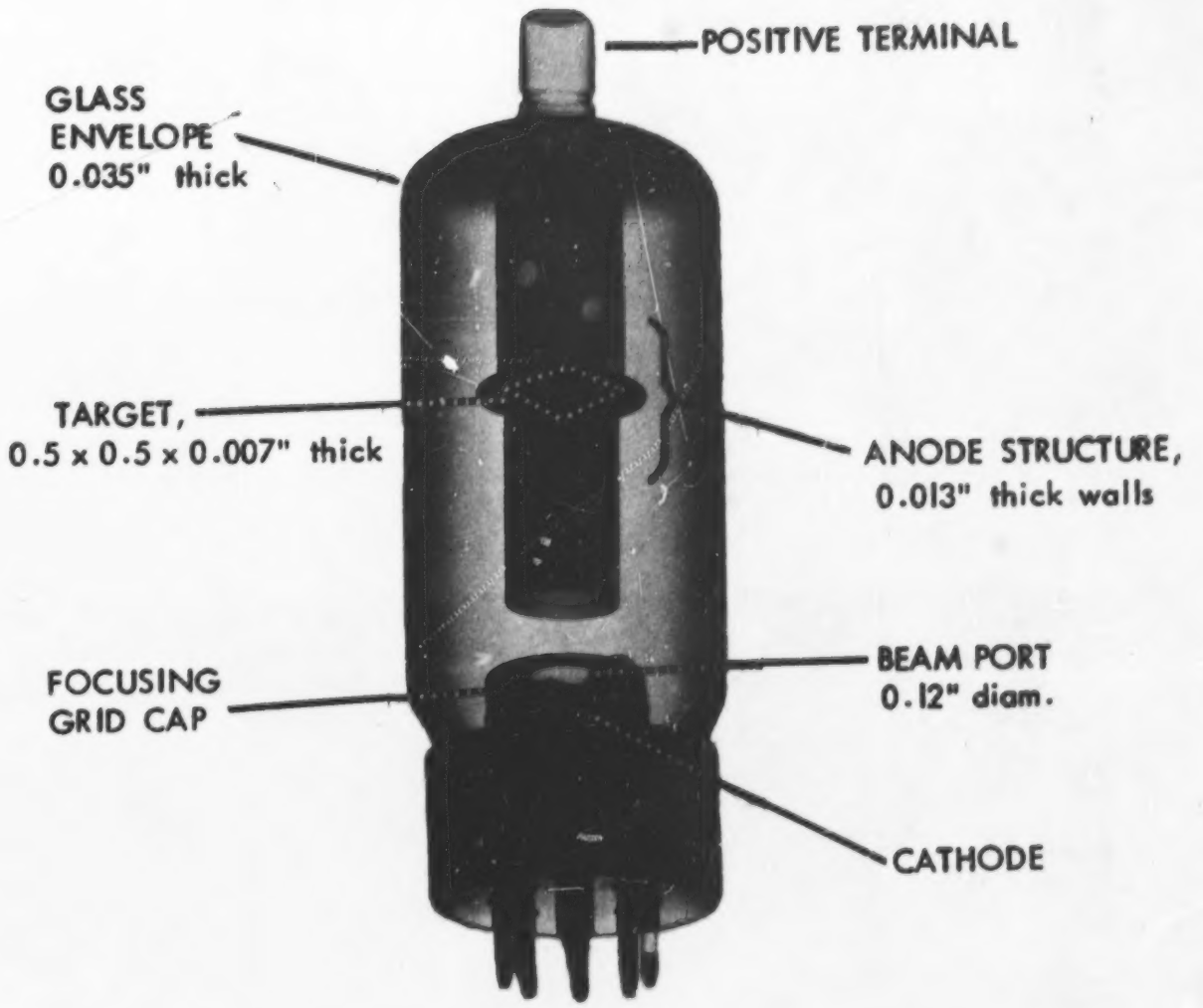
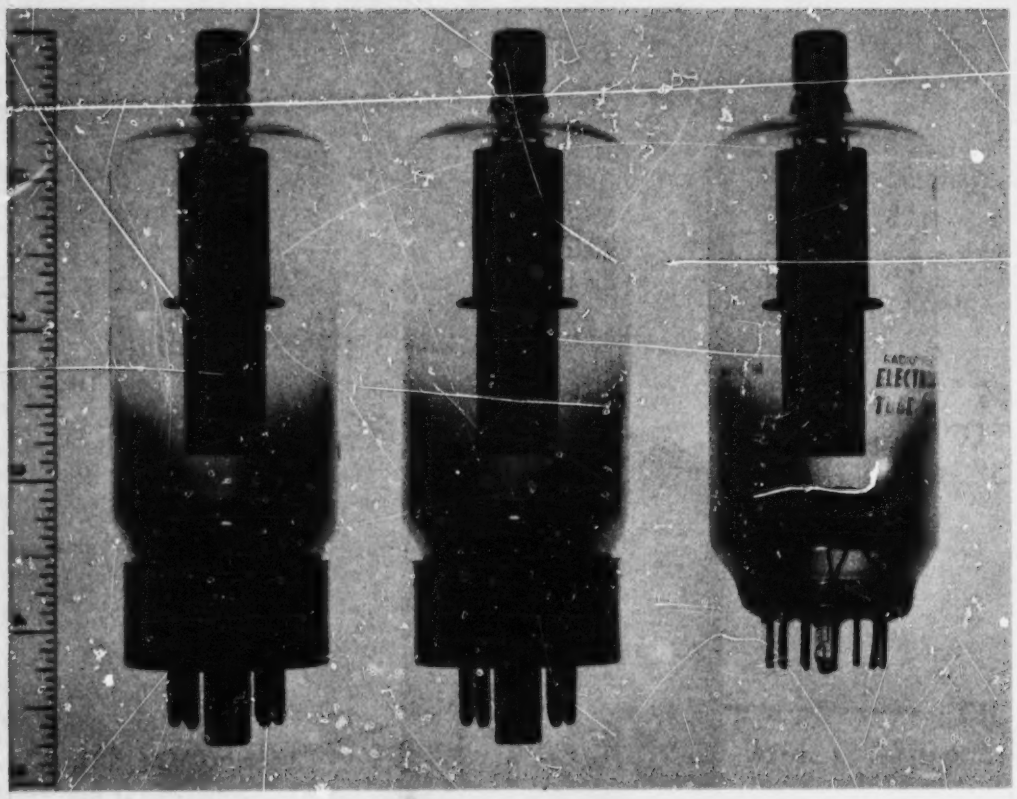


Fig. 1. Shunt regulator tube construction. This is a positive print from a radiograph of a 6LC6 tube.



6LC6 Modified 6LC6 6EF4

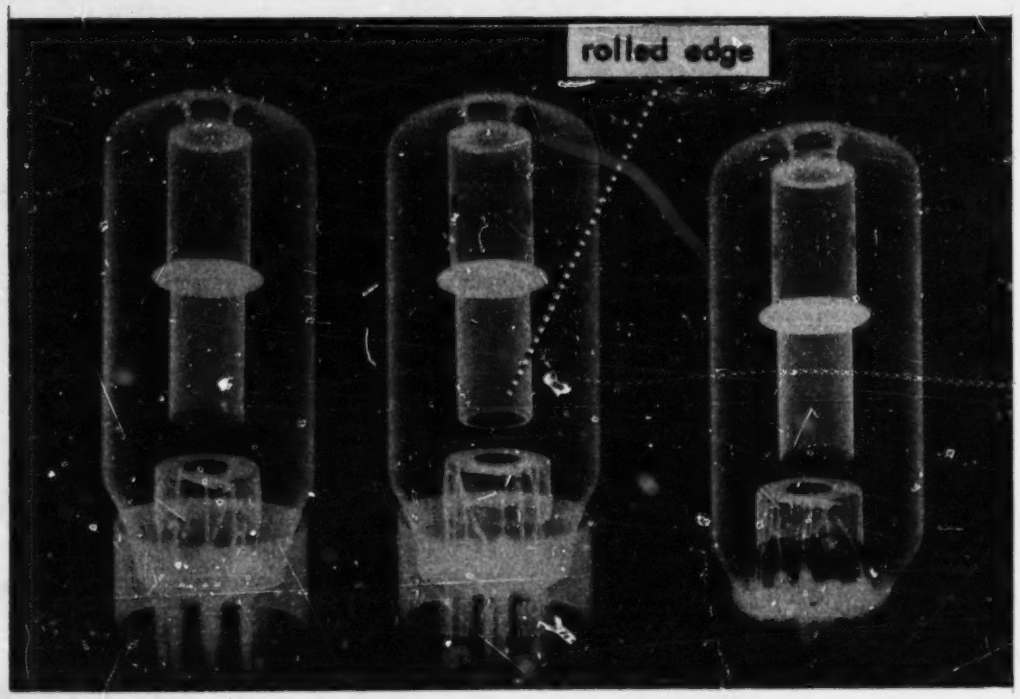


Fig. 2. Photograph and radiograph of typical shunt regulator tubes. The lower edge of the anode structure of the modified 6LC6 tube (center) is rolled to form a lip. The lip is designed to reduce x-ray leakage from misalignment.

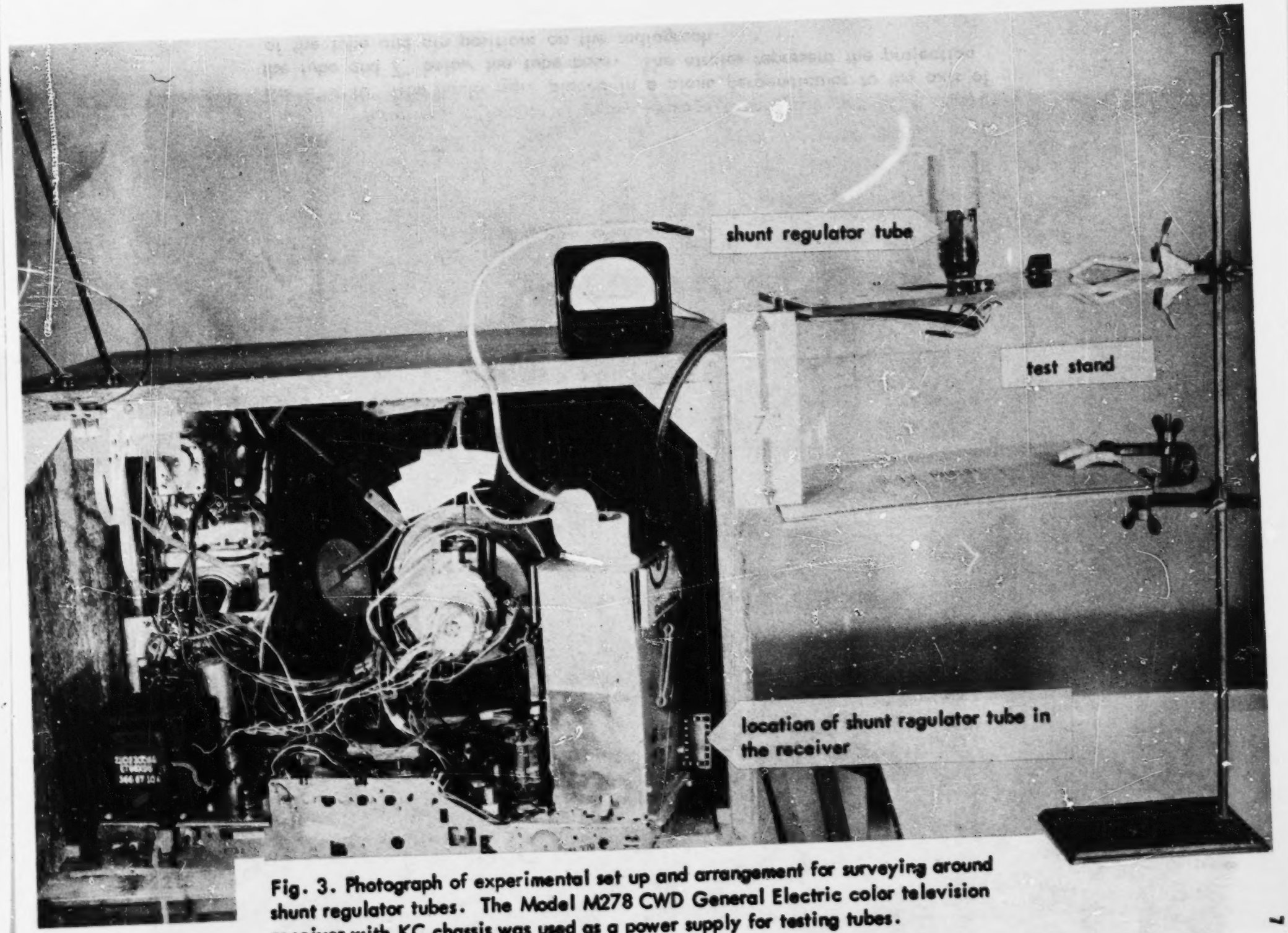


Fig. 3. Photograph of experimental set up and arrangement for surveying around shunt regulator tubes. The Model M278 CWD General Electric color television receiver with KC chassis was used as a power supply for testing tubes.

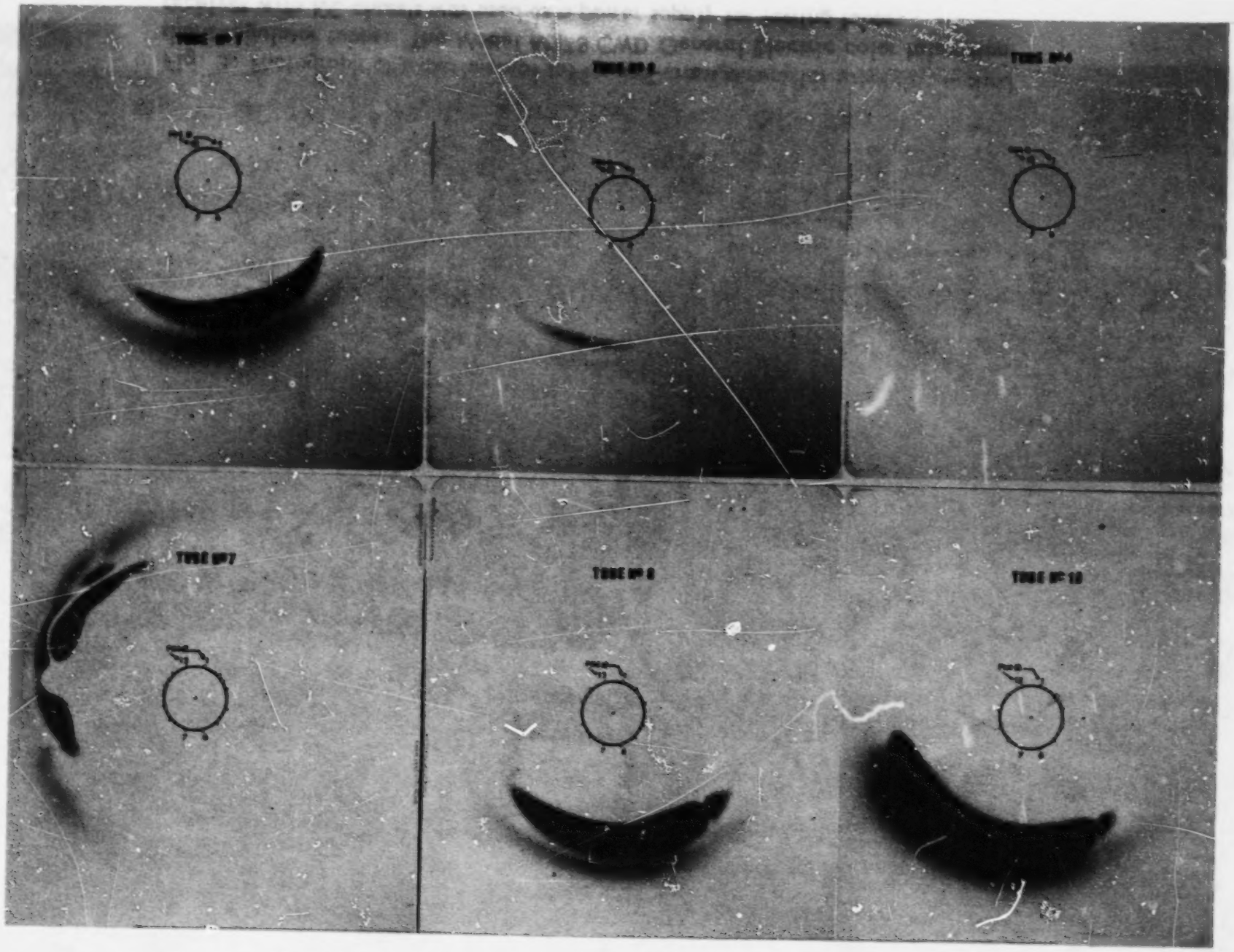
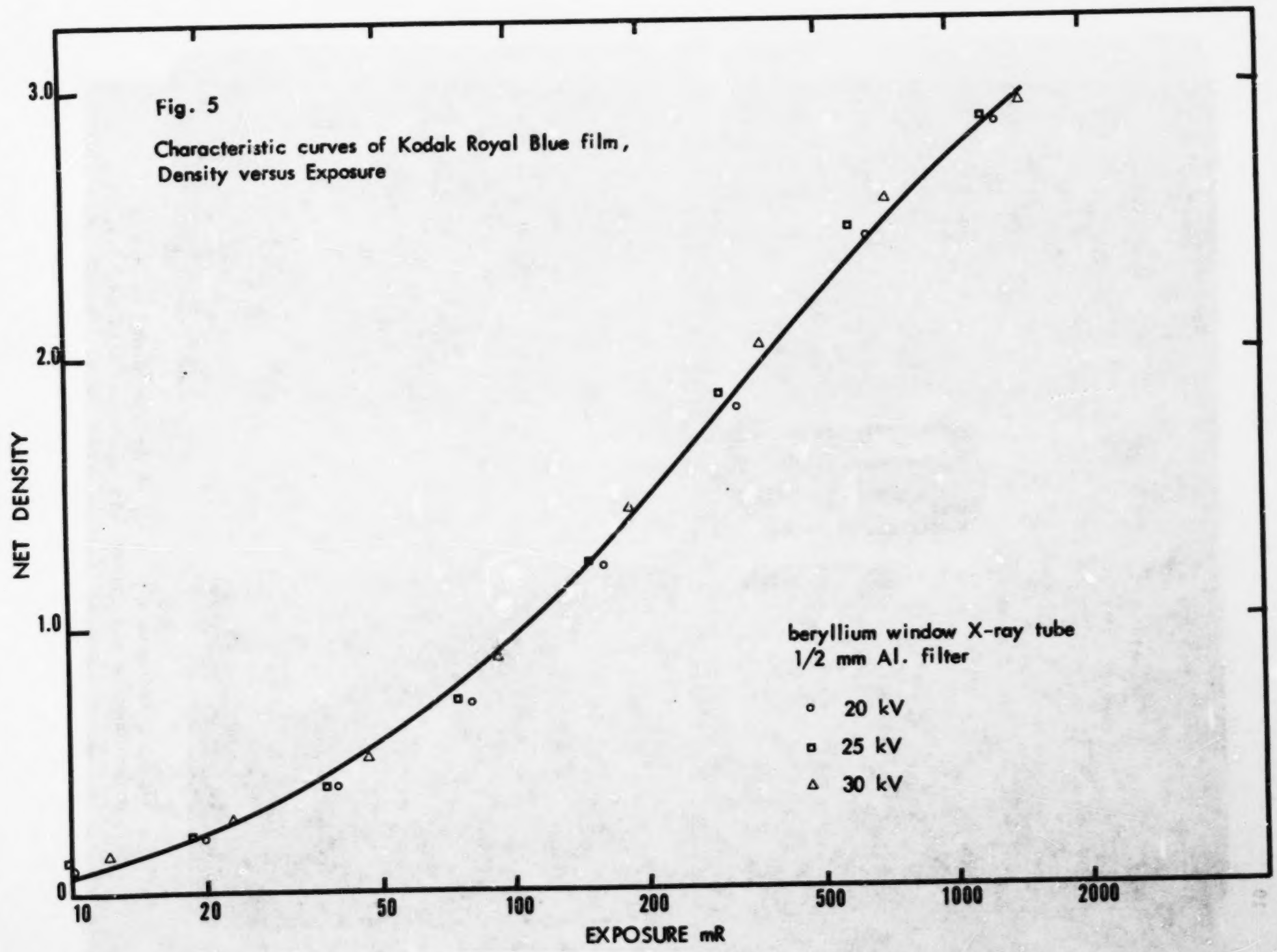


Fig. 4. Variations in images of x-ray leakage from misaligned 6EF4 tubes. The 8" x 10" film packs were placed in a plane perpendicular to the axis of the tube and 7" below the tube base. The circles represent the projection of the tube and pin positions on the radiograph.

Fig. 5

Characteristic curves of Kodak Royal Blue film,
Density versus Exposure



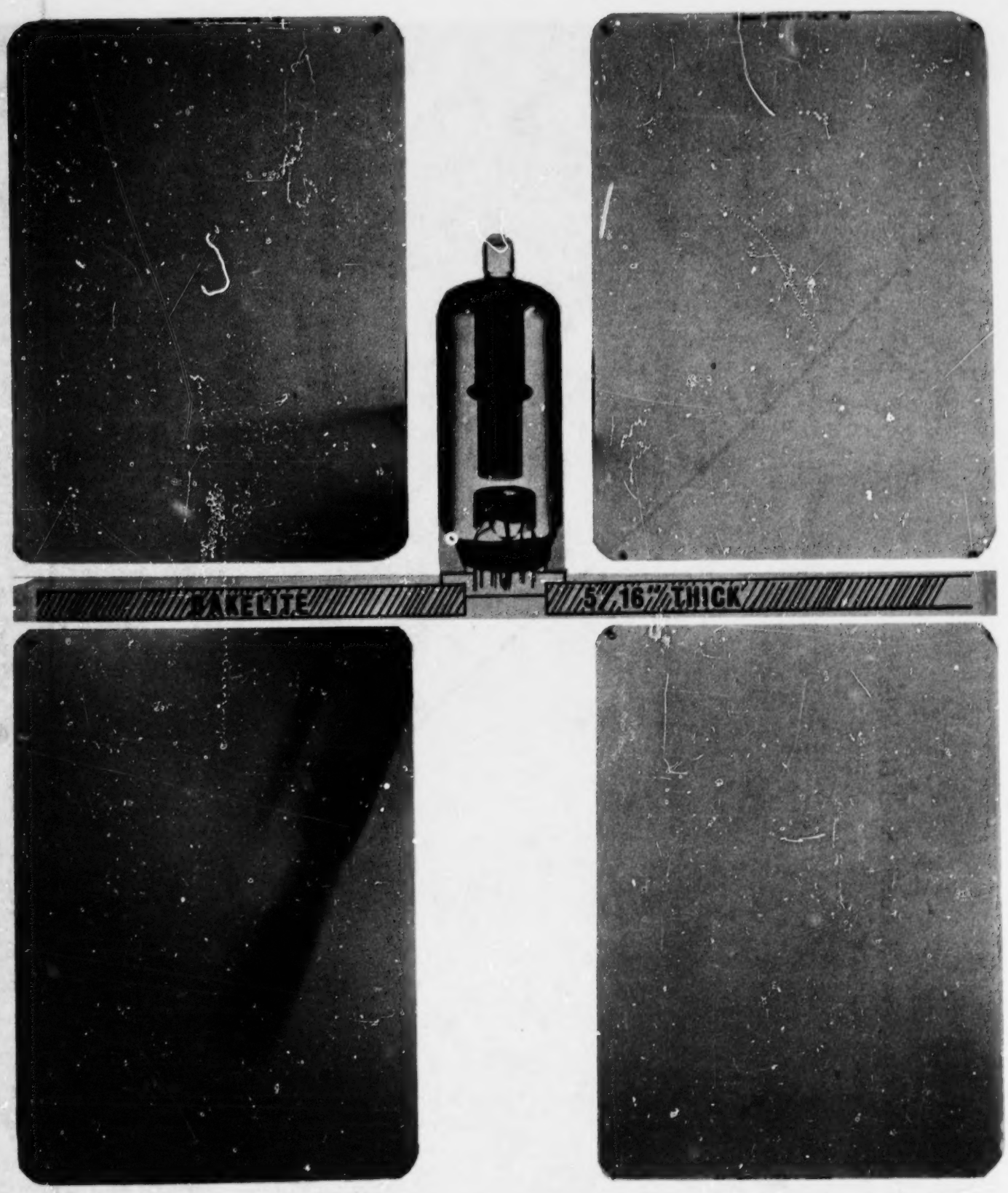


Fig. 6. Radiographs (5" x 7") of the lateral and oblique projection of x rays emitted from misaligned 6EF4 tube No. 10.

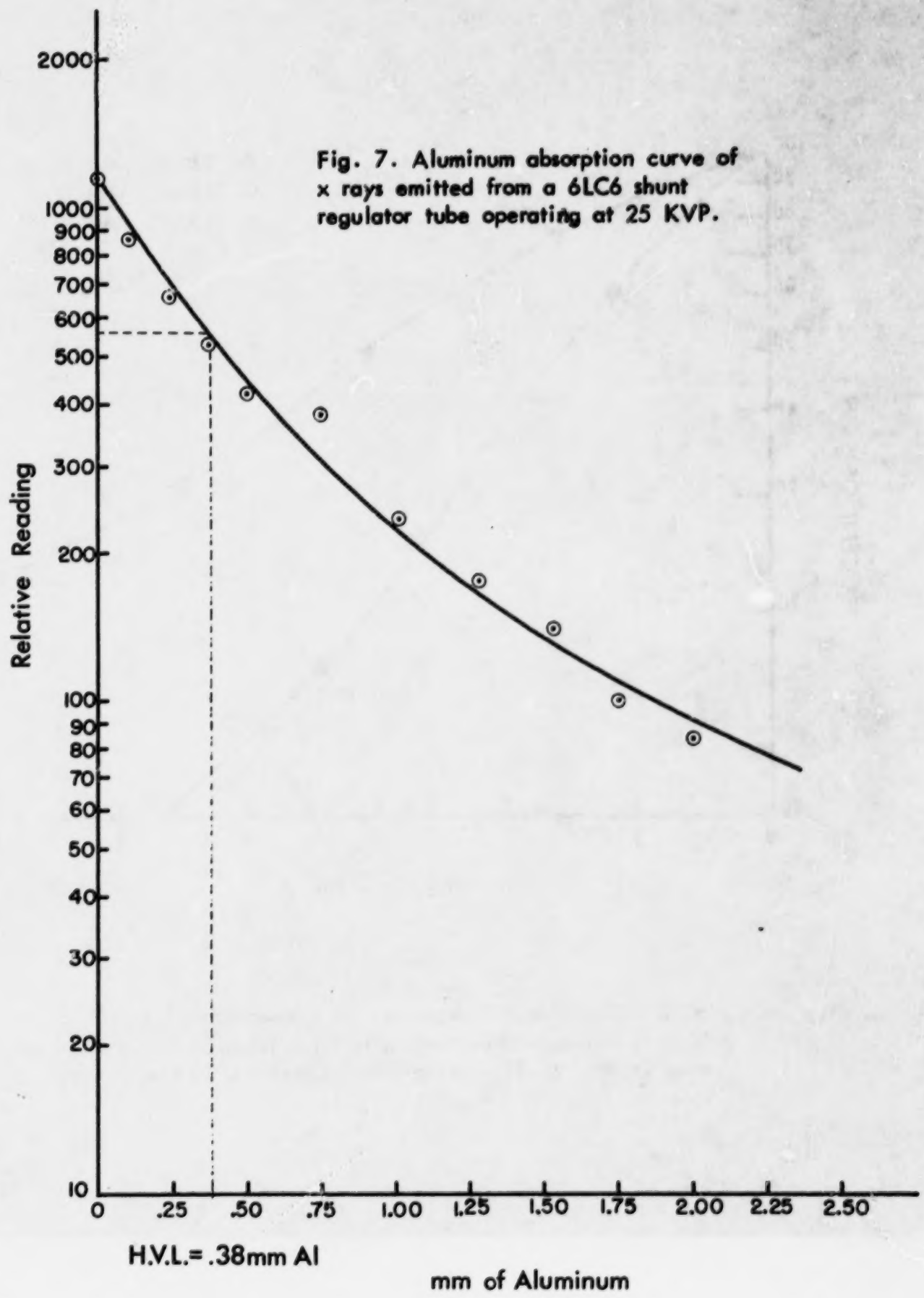


Fig. 7. Aluminum absorption curve of x rays emitted from a 6LC6 shunt regulator tube operating at 25 KVP.

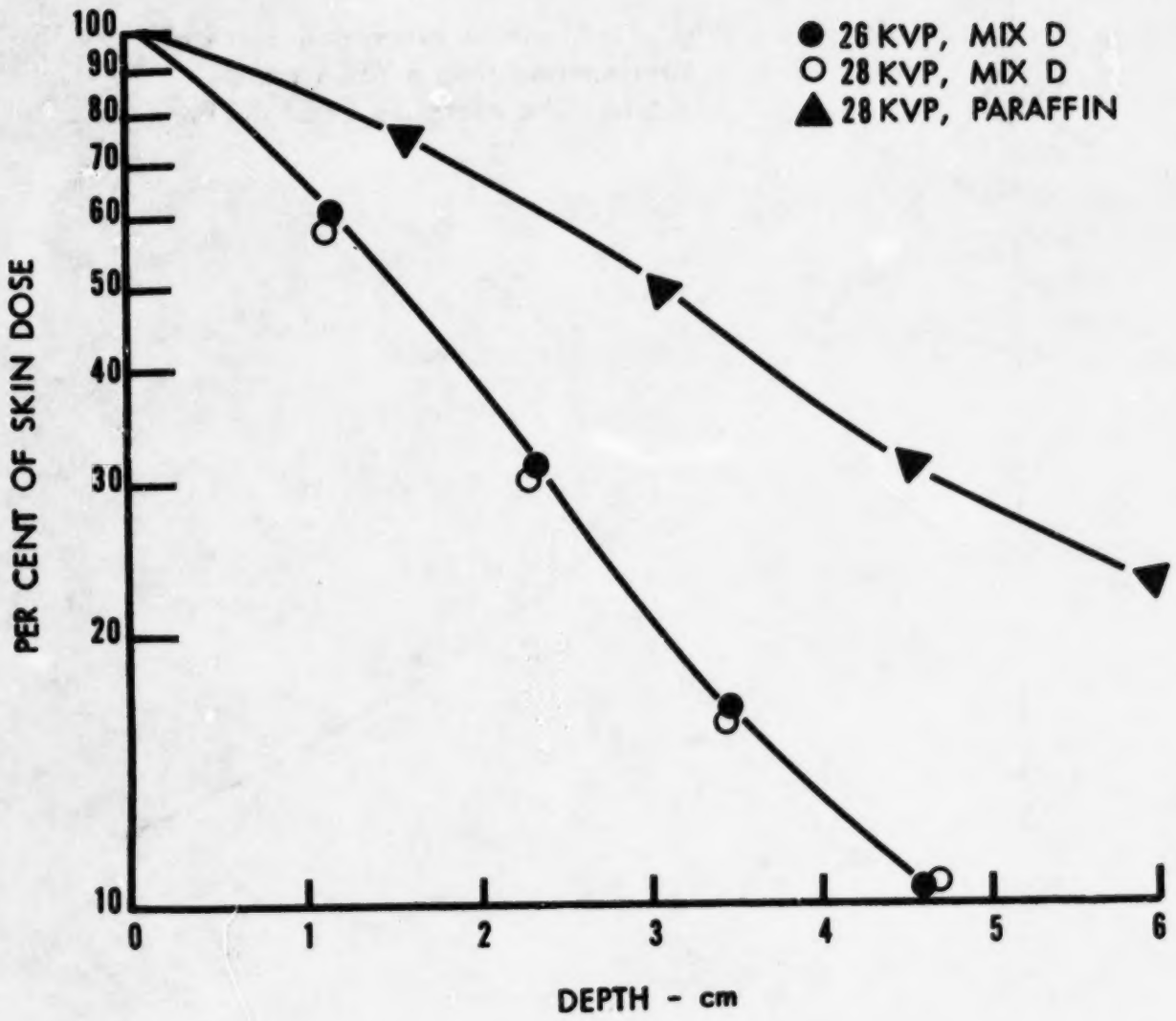


Fig. 8. Depth dose curves used in mammography. MIX D is a tissue equivalent material. From: Mammography, p. 74, Springfield: Charles C. Thomas (1964).

TABLE 1. --- SHUNT REGULATOR TUBES FOR COLOR TELEVISION RECEIVERS

Tube Type	Brand Name (2)	Actual Mfr.	Date of Initial Production	Design Max. Plate Voltage	Design Max. Plate Current	Notes
6BK4	SYL	See Note	Before '63	27 kV	1.6 mA	Tube designed by RCA, but manufactured by Sylvania.
6BK4A	RCA	RCA	10-63	27 kV	1.6 mA	
6BK4B	RCA	RCA	After 10-63	27 kV	1.6 mA	Rolled lip on bottom of anode cylinder.
6EA4	GE, RCA	GE	2-66	(1)	(1)	Replaced by 6EH4.
6EF4	RCA, GE	GE	Unknown	(1)	(1)	Replaced by 6EJ4.
6EH4	GE	GE	4-67	(1)	(1)	Replaces 6EA4, rolled lip on bottom of anode cylinder.
6EJ4	GE	GE	4-67	27 kV	1.6 mA	Replaces 6EF4(3)
6LC6	GE	GE	1-67	27 kV	1.6 mA	Replaced by 6LH6
6LH6	GE	GE	4-67	27 kV	1.6 mA	Replaces 6LC6(3)

(1) These tubes are too new for the specifications to be printed; however, they are probably rated at 27 kV and 1.6 mA since these values are adequate for all size color tubes now being made.
(2) Offered for sale by these companies under their own label. This may not be complete.
(3) Data sheets (product information) state that radiation measurements should be made with a properly calibrated survey meter.

TABLE 2. --- DISTRIBUTION AND EXPOSURE RATE OF X-RAY LEAKAGE BELOW SHUNT REGULATOR TUBE

Tube	Angle of Leakage (deg)*	Ion Chamber Expo. Rate @ 5" (mR/hr)**	Max. Image Width @ 7" (inches)	Max. Expo. Rate @ 7" (mR/hr)	Lip of Anode Cyl.
RCA 6EF4					
#1	18°	80	1/2	2000	Not rolled
2	24°	8	1/3	60	"
3	-	5	-	-	"
4	24°	7	1/2	45	"
5	-	Tube not functional		-	"
6	-	Tube not functional		-	"
7	22°	25	3/4	1700	"
8	18°	125	3/4	4000	"
9	-	5	-	-	"
10	20°	500	1	8000	"

Continued

TABLE 2 (Con't.)---DISTRIBUTION AND EXPOSURE RATE OF X-RAY LEAKAGE BELOW SHUNT REGULATOR TUBE

Tube	Angle of Leakage (deg)*	Ion Chamber Expo. Rate @ 5" (mR/hr)**	Max. Image Width @ 7" (inches)	Max. Expo. Rate @ 7"	Lip of Anode Cyl.
GE 6LC6					
#1	-	0.2	-	-	Rolled
2	-	Tube not functional		-	"
3	-	0.2	-	-	"
4	-	2.2	-	-	"
5	-	Tube not functional		-	Not rolled

*Angles were measured from tube axis to inner rim of crescent-shaped beam.(See sketch)

**Ion chamber exposure rate measurements were made with a Victoreen 440 RF survey meter at 5" from edge of chamber to bore of tube. Since only a fraction of the 3" diameter chamber was exposed to the leakage, it is to be expected that the ion chamber measurements would vary with the film exposure rates.

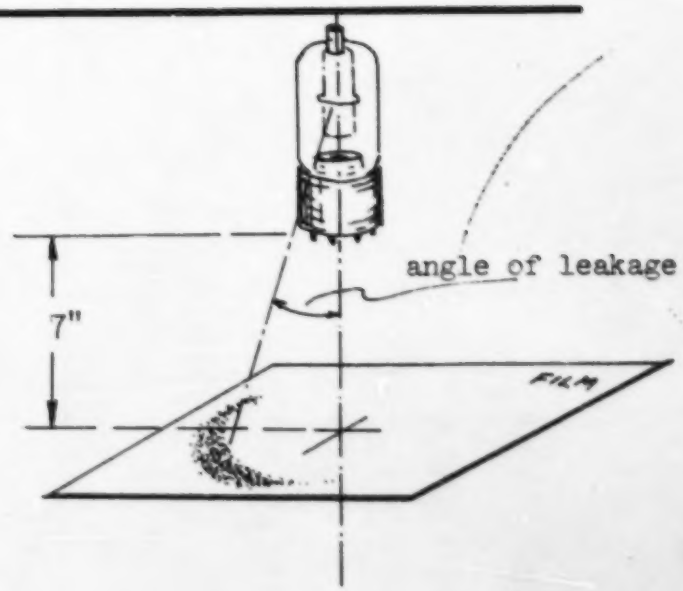


Table 3. --- INTERCOMPARISON OF SURVEY METER READINGS OF SHUNT REGULATOR TUBE X RADIATION

Instrument	Type of Instrument	Reading
Victoreen 440RF	Ion Chamber	40 mR/hr
Nuclear Chicago Model 2588	Ion Chamber	50 mR/hr
Nuclear Corp. of America CS-40	Ion Chamber	40 mR/hr
Victoreen CDV700	G-M Counter	50 mR/hr

BIBLIOGRAPHY

(1) BUSH, A.F., H.T. CASTBERG, AND D.G. MACPHERSON. X-ray Exposure in Manufacture and Operation of Certain Electronic Tubes. Public Health Reports, 59:1045 (Aug. 11, 1944).

(2) LARKS, S.D. Stray X-rays from Electron Beam Instruments and Some Biological Implications. Amer. Ind. Hygiene Assoc. Quart., 12:175-179 (Dec. 1951).

(3) BRAESTRUP, C.B., AND R.T. MOONEY. X-ray Emission from Television Sets. Science, 130:1071-1074 (Oct. 23, 1959).

(4) CALLENDER, M.V., AND D.F. WHITE. Aspect of the Emission of X-rays from Television Receivers. J. Brit. I.R.E., 21:387-400 (1961).

(5) BOURNE, L.B. X-ray Hazards from Television Apparatus and Cathode Ray Tubes. The Lancet, 6941:510 (1956).

(6) National Committee on Radiation Protection and Measurements (NCRP). Radiology, 75:122 (1960).

(7) Recommendations of the International Commission on Radiological Protection: ICRP Publication 3, Report of Committee III on Protection Against X-rays Up to Energies of 3 MeV and Beta- and Gamma-Rays from Sealed Sources, p. 14, London: Pergamon Press (1960).

(8) CIUCIURA, A. Assessment of X-Radiation from Television Receivers. J. Brit. I.R.E., 19:480 (1959).

(9) SHELDON, J.L. Design and Construction of Television Bulbs and Testing for X-ray Output. Seminar Presentation at the X-ray Exposure Control Laboratory, National Center for Radiological Health, Rockville, Maryland (Jan. 20, 1967).

(10) HAYASHI, S. et al. X-rays from Color Television Receivers. J. Radiation Research, 5-3-4:147-158 (1964).

(11) Nuclear-Chicago Corporation. Survey Meter Model 2588 Instruction Manual, pp. 3-4 (Feb. 1963).

(12) GRODSTEIN, G.W. X-ray Attenuation Coefficients from 10 keV to 100 MeV. National Bureau of Standards Circular 583, Washington, D. C. U. S. Government Printing Office (Apr. 30, 1957).

(13) OOSTERKAMP, W.J., J. PROPER, AND J.J.F. DEWIJK. Dosimetry or the Very Weak X-radiation Generated in Television Receivers and X-ray Diffraction Apparatus. Philips Tech. Rev., 19:264-267 (1957/1958).

(14) HAYASHI, M., AND S. HAYASHI. Absolute Dose Rate Measurement of Very Soft and Weak X-rays by Means of a GM Counter. J. Radiation Research, 5-3-4:172-182 (1964).

(15) EGAN, R.L. Mammography, p. 74, Springfield: Charles C. Thomas (1964).

(16) SAENGER, E.L. Medical Aspects of Radiation Accidents, p. 127, U. S. Atomic Energy Commission, Washington, D. C. U. S. Government Printing Office (1963).

(Appendix A)

GENERAL ELECTRIC COMPANY STATEMENT

SYRACUSE, NEW YORK--May 18, 1967

General Electric's Major Television Department has announced a program to modify some of its large screen color television sets. The program is being carried out on a national basis and should be completed by July 31. Modification involves replacement of the regular tube and adjustment of the power supply. Quality control tests indicate that some of these sets produced between June 1966 and February of this year may emit soft x-radiation in excess of desirable levels. When present, this emission is directed toward the floor and not toward the viewer. The picture tube is not involved.

Nationally recognized radiological health experts have confirmed preliminary Company findings that emissions have not been sufficient to cause harm to viewers. However, in view of its 26-year effort in providing customers with reliable and safe television receivers, the Company has a program well under way to make appropriate changes in the models involved. These changes will resolve any problems that may exist as well as materially improve performance and reliability.

Approximately 90,000 of these models have been sold. Sets currently available will be modified before sale. For sets already sold, General Electric service representatives are contacting customers who purchased these specific models manufactured since last June and will make the modifications without charge and at the customers' convenience.

Already identification is being achieved through mobilization of General Electric's entire distributor-dealer organization. Factory records, dealer sales records, warranty cards, service records and contract and finance records are among the many sources being used to derive this information. It is estimated that the program will be complete by the end of July. Set owners may wish to contact their dealer or service man if their set has not been modified by that time.

No black-and-white sets, no PortaColor sets and no sets purchased before June 1966 are involved in the modification.

(Appendix B)

U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
Public Health Service

Statement by James G. Terrill, Jr.,
Director, National Center for Radiological Health
of May 18, 1967
Concerning X-Radiation from Certain
General Electric Color Television Receivers

The General Electric Company recently advised us that it had started a modification program involving rework of certain large-screen console and table model color television receivers. I understand that the problem was in the high voltage power supply and does not involve the picture tube.

General Electric representatives informed us that the modification program was started because the Company found higher than desirable levels of x-ray production were created during the operation of some models of these color television sets in tests by the Company. This emission is directed through the bottom of the set, toward the floor, and not toward the viewer.

Studies made by the National Center for Radiological Health of several television sets during the past six months did not give rise to concern. All of the sets tested gave off radiation well below the limits (.5 mR/hour) recommended by the National Council for Radiation Protection.

The General Electric Company stated black-and-white or small-screen "PortaColor" sets are not involved. It identified the sets about which it is concerned as certain large-screen color TV receivers manufactured between June 1966 and February 1967, and purchased after September 1, 1966. The Company advised us that its entire distributor-dealer service organization has been mobilized to contact owners of such television sets to arrange for the modification, and that modification will be made without charge to the customer.

As of now there is no evidence in the hands of the NCRH to suggest that any television receivers manufactured by the General Electric Company, or television sets made by other companies, have excessively exposed viewers of television sets.

The ABSTRACT CARDS below are designed to facilitate document retrieval using Coordinate Indexing. They provide space for an accession number (to be filled in by the user), suggested key words, bibliographic information, and an abstract.

The Coordinate Index concept of reference material filing is readily adaptable to a variety of filing systems. Coordinate Indexing is described in the publication "IBM Data Processing Techniques - Index Organization for Information Retrieval" (C 20-8062). Copies are available through IBM Branch Offices.

The cards are furnished in triplicate to allow for flexibility in their use (e.g., author card index, accession number card index.)

Accession No.

X-RAY EMISSION FROM SHUNT REGULATOR TUBES FOR COLOR TELEVISION RECEIVERS - E. Murphy, H. Stewart, S. Coppola, N. Modine; June 1967; MORP 67-1, XECL, MORP, NCRH, PHS, DHEW.

This laboratory report summarizes investigations by the Public Health Service of X-ray emission from shunt regulator tubes used in color television receivers. Tables, photographs, and bibliography are presented and conclusions are discussed.

KEY WORDS

Television, Exposure, X-ray, Electronic Products, Radiation, Electron Tubes.

Accession No.

X-RAY EMISSION FROM SHUNT REGULATOR TUBES FOR COLOR TELEVISION RECEIVERS - E. Murphy, H. Stewart, S. Coppola, N. Modine; June 1967; MORP 67-1, XECL, MORP, NCRH, PHS, DHEW.

This laboratory report summarizes investigations by the Public Health Service of X-ray emission from shunt regulator tubes used in color television receivers. Tables, photographs, and bibliography are presented and conclusions are discussed.

KEY WORDS

Television, Exposure, X-ray, Electronic Products, Radiation, Electron Tubes.

Accession No.

X-RAY EMISSION FROM SHUNT REGULATOR TUBES FOR COLOR TELEVISION RECEIVERS - E. Murphy, H. Stewart, S. Coppola, N. Modine; June 1967; MORP 67-1, XECL, MORP, NCRH, PHS, DHEW.

This laboratory report summarizes investigations by the Public Health Service of X-ray emission from shunt regulator tubes used in color television receivers. Tables, photographs, and bibliography are presented and conclusions are discussed.

KEY WORDS

Television, Exposure, X-ray, Electronic Products, Radiation, Electron Tubes